

3.1 Density of materials

Name: _____ Class: _____ Date: _____

Total: 25 marks

KEY WORDS density

Objective

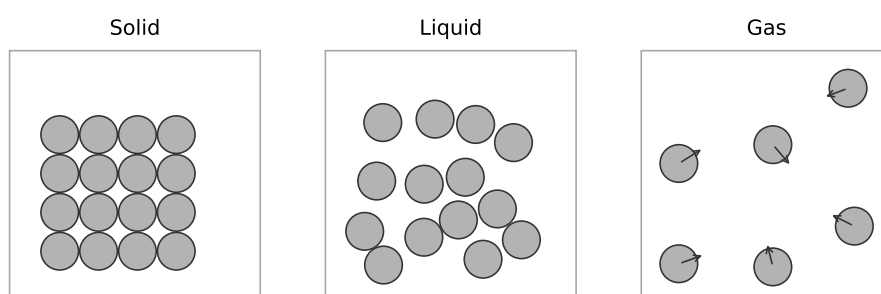
Use $\rho = m/V$ with kg/m^3 and g/cm^3 , explain densities with the particle model, and describe RP5 for regular solids, displacement and liquids. Original questions for specification 4.3.1.1 and required practical 5.

1 Key knowledge and worked examples

$$\rho = \frac{m}{V}$$

Wanted	Rearranged form
ρ	$\rho = m/V$
m	$m = \rho V$
V	$V = m/\rho$

Use consistent units and show conversions when needed: $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$; $1 \text{ cm}^3 = 10^{-6} \text{ m}^3$; tonnes $\times 1000 \rightarrow \text{kg}$.



Same-sized schematic particles; equal viewing volumes

Draw these from memory: pattern, contact, spacing.

State	Arrangement	Density trend
solid	close, regular	often greater than liquid; exceptions exist
liquid	touching, sliding	close to the solid
gas	far apart, random	much lower

Solids and liquids pack similarly, so their densities are similar; a gas is mostly empty space. Water is the famous exception: ice floats because freezing expands it.

Worked example. A metal ring has mass 9.46 g and volume 0.44 cm³. Find ρ in kg/m³.

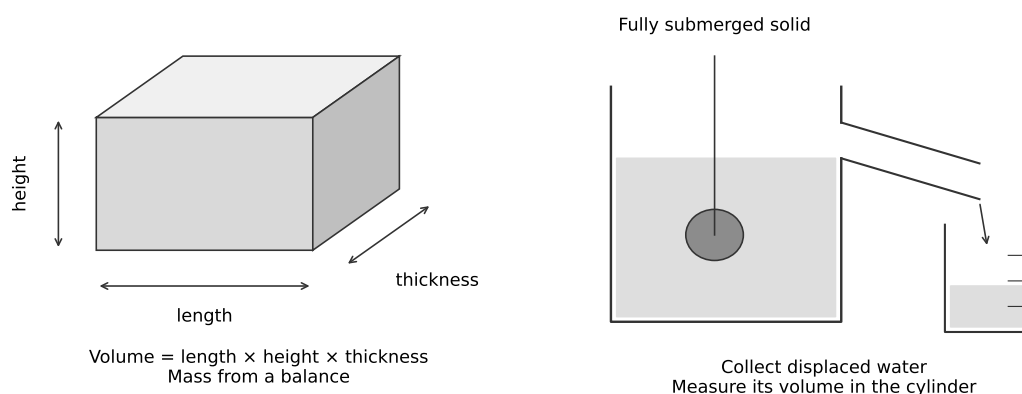
- Convert both quantities before substituting.

$$m = 9.46 \text{ g} = 9.46 \times 10^{-3} \text{ kg}, \quad V = 0.44 \text{ cm}^3 = 4.4 \times 10^{-7} \text{ m}^3$$

$$\rho = \frac{m}{V} = \frac{9.46 \times 10^{-3} \text{ kg}}{4.4 \times 10^{-7} \text{ m}^3} = 21\,500 \text{ kg/m}^3$$

- Check: values around $2 \times 10^4 \text{ kg/m}^3$ are plausible for a dense metal.

RP5 method marks:



Dimensions for regular objects; displaced water for irregular ones.

- **Regular solid:** measure length, width, thickness (ruler, micrometer or callipers); $V = l \times w \times t$; mass on a balance.
- **Irregular solid:** overflow a displacement can, lower the object on **thin** string; the collected water's volume equals the object's volume.
- **Liquid:** weigh an empty measuring cylinder, add a known volume, subtract for the mass.
- Accuracy: read cylinders at eye level; wait for dripping to stop; repeat and average; thin string displaces almost nothing.

2 Practice

2.1 A block measures $4.0\text{ cm} \times 2.0\text{ cm} \times 5.0\text{ cm}$ and has mass 352 g . Calculate its density in kg/m^3 . [3]

2.2 State why a gas has a much lower density than its liquid, using the particle model. [2]

2.3 Seawater of density 1030 kg/m^3 flows at $824\,000\text{ kg}$ per second. Calculate the volume passing each second. [3]

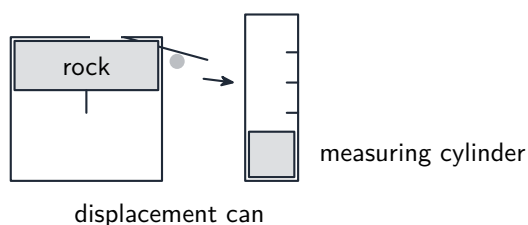
3 Exam-style questions

3.1 A student determines the density of a rock.

(a) Describe a method using a displacement can and a measuring cylinder. [4]

(b) The rock's mass is 84 g and the collected water is 33 cm^3 . Calculate the density in g/cm^3 . [2]

(c) Convert your answer to kg/m^3 . [1]



3.2 A student measured the volume of a metal ring with a measuring cylinder: water rose from 5.0 cm^3 to 5.4 cm^3 .

(a) The true volume is 0.44 cm^3 . Give one reason why the cylinder cannot give an accurate value. [1]

(b) The student used thick string to lower the ring. Explain whether this makes the measured volume too large or too small. [2]

(c) The balance read 0.02 g after removing the ring. State how to correct the mass reading. [1]

3.3 A jeweller mixes copper (density 8900 kg/m^3) and zinc (7100 kg/m^3) to make 0.50 kg of brass of density 8500 kg/m^3 . Assume volumes add.

(a) Write an equation for the total volume in terms of the copper mass m . [2]

(b) Solve for the copper mass. [3]

(c) State one assumption about the mixing. [1]

Solutions

2.1 Volume: $V = 4.0 \times 2.0 \times 5.0 = 40 \text{ cm}^3 = 4.0 \times 10^{-5} \text{ m}^3$ (C1); mass $m = 0.352 \text{ kg}$ (C1).

$$\rho = \frac{0.352 \text{ kg}}{4.0 \times 10^{-5} \text{ m}^3} = \mathbf{8800 \text{ kg/m}^3}$$

(answer with unit A1.)

2.2 In a gas the particles are much further apart, so the same number of particles occupies a far larger volume – most of a gas is empty space.

2.3 Rearrange first: $V = m/\rho$ (C1); per second, $m = 824\,000 \text{ kg}$ (C1).

$$V = \frac{824\,000 \text{ kg}}{1030 \text{ kg/m}^3} = \mathbf{800 \text{ m}^3}$$

(answer A1.)

3.1 (a) Fill the displacement can to the spout and let it finish dripping; lower the rock fully on thin string; collect the displaced water in a measuring cylinder read at eye level; the volume collected equals the rock's volume, and the mass from a balance gives $\rho = m/V$.
(b)

$$\rho = \frac{84 \text{ g}}{33 \text{ cm}^3} = \mathbf{2.5 \text{ g/cm}^3} \text{ (2 s.f.)}$$

(division 1, answer with unit 1.) (c) $2.5 \times 1000 = \mathbf{2500 \text{ kg/m}^3}$.

3.2 (a) The cylinder's resolution (0.2 cm^3 divisions) is too coarse for a 0.44 cm^3 object.
(b) The thick string displaces extra water, so the measured volume is too large – and the density comes out too small. (c) Subtract 0.02 g from each reading.

3.3 (a) Zinc mass = $0.50 - m$; volumes add:

$$V_{\text{total}} = \frac{m}{8900} + \frac{0.50 - m}{7100} \quad \text{and} \quad V_{\text{total}} = \frac{0.50}{8500}$$

(equation set up C1, both volume terms A1.) (b) Multiply through by the denominators (or equate):

$$\begin{aligned} \frac{m}{8900} + \frac{0.50 - m}{7100} &= \frac{0.50}{8500} \\ 7100m + 8900(0.50 - m) &= \frac{0.50 \times 8900 \times 7100}{8500} \\ 7100m + 4450 - 8900m &= \frac{0.50 \times 8900 \times 7100}{8500} = 3717.0588 \dots \\ 1800m &= 4450 - 3717.0588 \dots = 732.9412 \dots \\ m &= 732.9412 \dots / 1800 = 0.40719 \dots \text{ kg} \\ m &= \mathbf{0.41 \text{ kg}} \text{ (copper)} \end{aligned}$$

(algebra C1, substitution C1, answer A1.) (c) Any one: the volumes simply add (no contraction on mixing); the densities stay as tabulated in alloy form.